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SHORT COMMUNICATION

Better postoperative oxygenation in thoracoscopic esophagectomy in prone positioning

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Abstract Intrathoracic procedures can be performed with thoracoscopy in esophagectomy because the laparoscopic technique has recently been developed. During intrathoracic procedures, prone positioning of the patient allows gravity to facilitate optimal exposure of the esophagus, thereby affording a superb surgical view. In the current study, we compared the influence of prone positioning with lateral decubitus positioning on oxygenation in esophagectomy. We enrolled 18 patients and divided them into two groups: patients who underwent esophagectomy via thoracoscopy in the prone position (group P) and patients who underwent thoracotomy in the lateral decubitus position (control group, group L). Arterial blood gas analyses were performed before the operation was started (T1), 20 min after the initiation of one-lung ventilation (OLV) (T2), and two other points. The *P*/*F* ratio at T2 in group P was higher. Further, percent (%) change of the *P*/*F* ratios from T1 and thereafter in group P was higher at all points. We thought the reason why the prone position had contributed to maintenance oxygenation was as follows. First, the functional residual capacity and ventilation/perfusion matching in the prone position are satisfactory. Second, a bronchial blocker might contribute to reduction of atelectasis. Third, minimally invasive esophagectomy might reduce respiratory complications and blood loss because this procedure reduces edema and inflammation in the lung. In conclusion, the oxygenation provided by prone positioning is better than that provided by the lateral decubitus position during OLV in esophagectomy.

Keywords Esophagectomy · Prone position · One-lung ventilation

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Esophagectomy is a highly invasive surgical procedure, and postoperative pulmonary complications are the primary complications associated with this procedure. A combined thoracoabdominal approach for esophagectomy is the largest factor contributing to the morbidity and mortality caused by postoperative pulmonary complications [1, 2]. However, owing to recent developments in laparoscopic techniques, intrathoracic procedures can be performed using thoracoscopy. Prone positioning of the patient during an intrathoracic procedure facilitates optimal exposure of the esophagus by means of the anatomical orientation in the prone position, thereby affording an excellent surgical view [3]. Furthermore, good exposure of the esophagus is achieved by inducing a transitory pneumothorax using carbon dioxide (CO_2) [4]. Hemodynamics are well maintained throughout the procedure, and the respiratory changes are acceptable [5]. However, respiratory changes in the prone position have not been compared with values in the lateral decubitus position during esophagectomy. Therefore, we investigated the influence of the prone and lateral decubitus positions on oxygenation in esophagectomy.

We obtained approval from the ethics committee of our hospital, and the patients provided written informed consent. We enrolled patients who underwent esophagectomy with thoracoscopy in the prone position between July 2009 and December 2009 (group P) and those who underwent thoracotomy in the lateral decubitus position between April

Table 1 Patient demographic and perioperative data and results of blood gas analysis

	Group P ($n = 9$)	Group L ($n = 9$)
Demographics		
Age (year)	66 ± 5	63 ± 6
Weight (kg)	55 ± 8	57 ± 10
Height (cm)	158 ± 7	163 ± 7
Gender (F/M)	3/6	1/8
Time (min)		
Operation	670 ± 69	$567 \pm 50^{\#}$
One-lung ventilation	275 ± 34	$149 \pm 23^{\#}$
Anesthesia	743 ± 71	$657 \pm 51^{\#}$
Intubation	616 ± 65	$1031 \pm 291^{\#}$
Total amount (ml)		
Infusion	3022 ± 433	$4883 \pm 1206^{\#}$
Bleeding	208 ± 112	$440 \pm 229^{*}$
Urine volume	1735 ± 660	1372 ± 640
Duration (days)		
ICU stay	1.0 ± 0.0	1.2 ± 0.3
Hospital stay	30 ± 23	33 ± 12
P/*F* ratio (mmHg)		
T1	456 ± 54	460 ± 51
T2 (% change from T1)	$204 \pm 85^{+}$ (44 ± 14)	$145 \pm 57^{*+}$ $(31 \pm 12)^{*}$
T3 (% change from T1)	465 ± 49 (103 ± 10)	429 ± 84 $(93 \pm 13)^{*}$
T4 (% change from T1)	443 ± 113 (98 ± 24)	$373 \pm 87^{+}$ $(80 \pm 15)^{*}$

Data are mean ± SD

T time, PaO_2 partial pressure of oxygen, *ICU* intensive care unit, *P*/*F ratio* the ratio of PaO_2 to fraction of inspired oxygener, $PaCO_2$ partial pressure of carbon dioxide

* $P < 0.05$ different between the groups

\# $P < 0.01$ different between the groups

\+ $P < 0.01$ different from T1

2008 and June 2009 (control group, group L). Before the induction of anesthesia, an epidural catheter was inserted at the level of T8–T9. Propofol, vecuronium, and fentanyl were used to induce anesthesia, and anesthesia was maintained with propofol, remifentanil, vecuronium, and epidural anesthesia. The patients received pressure-controlled ventilation with a tidal volume of 6–12 ml/kg and FiO_2 of 0.5–1.0.

In group P, lymphadenectomy in the neck was performed in the supine position. After this procedure, the patient was placed in the prone position. A negative pressure bag was placed under the chest, and ProneView (Dupaco, Oceanside, CA, USA) was used for protection of the skin and eyeball. During thoracoscopy, one-lung ventilation (OLV) was performed using TCB bronchial blocker (Fuji Systems, Tokyo, Japan), and CO_2 insufflation was maintained at 6 mmHg. At the end of thoracoscopy, the patient was returned to the supine position. After total laparoscopic gastric mobilization (TLGM) [6], tube formation was performed through a small incision. Finally, esophagogastric anastomosis was performed.

In group L, the neck procedure, TLGM, and tube formation were performed in the supine position. Thoracotomy was performed after placing the patient in the lateral decubitus position. OLV was performed using a double-lumen endotracheal tube. Finally, esophagogastric anastomosis was performed in the supine position.

In both groups, positive end-expiratory pressure (PEEP) and respiratory rate were adjusted by the individual anesthesiologists. Patients were extubated when a spontaneous tidal volume of 5–6 ml/kg with a pressure support of 5 mmHg or less, a PEEP of 5 mmHg, a respiratory rate of less than 20 breaths per minute, and a partial pressure of oxygen (PaO_2) of more than 120 mmHg with FiO_2 of less than 0.4 were achieved in the intensive care unit (ICU). However, the individual anesthesiologists made the final decision whether extubation was performed.

Arterial blood gas analyses were performed before the operation was started (T1), 20 min after the initiation of OLV (T2), at the completion of the operation (T3), and 20 min after extubation in the ICU (T4). Duration of operation, anesthesia, and intubation was recorded. During the operation, the total amount of bleeding, infusion, and urine volume were measured.

Data are presented as mean ± standard deviation (SD). Statistical analysis were performed using a statistical software package (ystat2002.xls; Igakutosho Shuppan, Tokyo, Japan). The data for the groups were compared using the Mann–Whitney *U* test. Changes between time points within a group were compared using the Bonferroni correction. *P* values less than 0.05 were considered to be statistically significant.

We enrolled a total of 18 patients. The amount of bleeding and infused fluid were significantly lower in group P

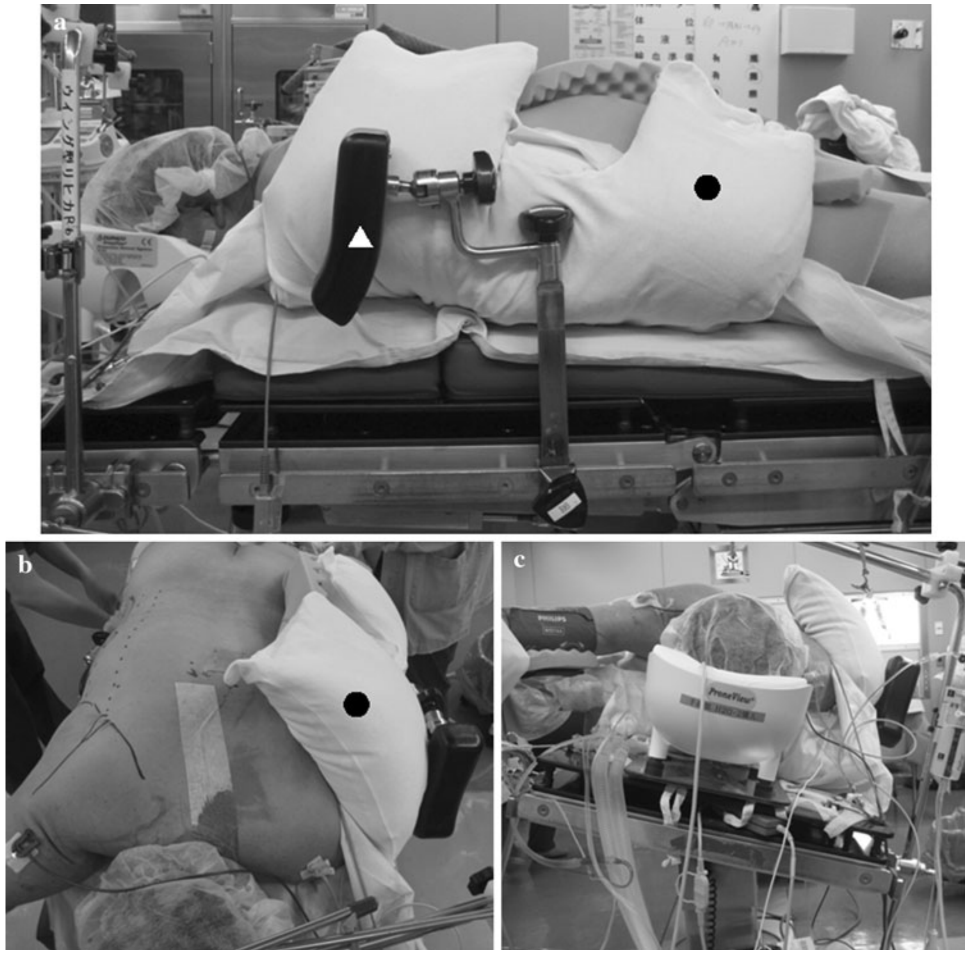

Fig. 1 **a**, **b** A bank is built on the left side of the patient using a negative pressure bag (*black circle*). This bank is fixed to the surgical table using a brace (*white triangle*). **c** The surgical table is tilted to 30°, and a lateral position is achieved

than in group L. The time between ICU admission and extubation in group P was significantly shorter than that in group L. However, the total time required for operation, one-lung ventilation, and anesthesia was longer in group P than that required in group L. There was no significant difference between the ventilator settings at all points in the two groups. No difference was noted in the ratio of PaO_2 to F_IO_2 (*P*/*F* ratio) at T1 (Table 1). However, the *P*/*F* ratio at T2 in group P was significantly higher than that in group L. Further, percent (%) change of the *P*/*F* ratios from T1 and thereafter in group P were higher than those in group L at all points. Partial pressure of carbon dioxide ($PaCO_2$) at T2 in group P was significantly higher than that in group L (48 ± 6 vs. 43 ± 3 mmHg; $P < 0.05$). There was no significant difference between pH at all points in both groups. No complications occurred during anesthesia and ICU stay in either group. There were no significant differences between the two groups with respect to the duration of ICU stay, hospital stay, and time until resumption of food intake (postoperative day 21 ± 22 vs. 19 ± 11, respectively).

Our data showed that the prone position approach provided good oxygenation and reduced bleeding in esophagectomy. This finding indicates that the prone position is a useful technique for esophagectomy. Unfortunately, we did not measure the functional residual capacity (FRC). Hence, we could not determine the reason why the prone position had contributed to maintenance oxygenation. However, this mechanism may be explained as follows. First, in the lateral decubitus position, the functional residual capacity (FRC) of the ventilated lung is decreased because of a decrease in neural output to the diaphragm or an increase in the expiratory tone of the abdominal muscles, which increases the intraabdominal pressure and displaces the diaphragm cephalad [7]. In addition, the ventilated lung is pressed by the mediastinum and the non-ventilated lung, thereby leading to atelectasis. In contrast, the FRC and ventilation/perfusion matching in the prone position are satisfactory [5]. Therefore, oxygenation during and after OLV in the prone position is better than that in the lateral decubitus position. Second, a bronchial blocker might contribute to reduction of atelectasis. The use of a double-lumen endotracheal tube leads almost completely to lung collapse. Although this method provides the optimal surgical view, atelectasis occurs widely. However, a bronchial blocker does not lead to a complete collapse. Therefore, the *P*/*F* ratio at T3 and T4 in group P was maintained despite the long duration of one-lung ventilation and anesthesia. Furthermore, the time between ICU admission and extubation in group P was significantly shorter than that in group L because of reduction of atelectasis. The shorter duration of intubation decreases the risk of pneumonia [8] and improves the patient's outcome. In fact, late development of pneumonia was less in group P than that in group L (0 vs. 22%). However, this difference was not statistically significant because the sample size was small. Third, Bussieres suggested that minimally invasive esophagectomy might reduce respiratory complications and blood loss [9]. We speculate that controlled hemorrhage was a prerequisite for laparoscopic surgery so as not to impair the surgical view during the procedure. Furthermore, laparoscopy allows easy detection of the origin of small hemorrhages. In this study, the total amount of blood loss and infusion was less in group P than that in group L. We thought that these factors might reduce edema and inflammation in the lung. Thus, minimally invasive esophagectomy performed with the patient in the prone position and by using a bronchial blocker contributed to improving postoperative oxygenation.

One of the problems encountered when the patient is in the prone position is unexpected bleeding. Countermeasures to unexpected bleeding must be undertaken in this approach. We recommend that a bank be built on the left side of the patient using a negative pressure bag to avoid unexpected bleeding during the operation. This bank is fixed to the surgical table using a brace (Fig. 1). The surgical table is tilted to 30°. A lateral position is achieved, and the surgeon can perform thoracotomy.

We recognize that there are some limitations to our study because this is a pilot study. Sample size was small, and the patients were not randomized to the surgical position. In addition, the prone group had minimally invasive surgery and the lateral group had a thoracotomy, and the prone group had bronchial blockers and the lateral group double-lumen tubes. These other differences could have contributed to the PaO_2 differences between the groups. Therefore, further randomized clinical trials are required to elucidate whether thoracoscopic esophagectomy in the prone position can contribute to improving postoperative oxygenation and patient outcome.

In conclusion, the oxygenation provided by prone positioning is better than that provided by the lateral decubitus position during OLV in esophagectomy. Surgery in the prone position may contribute to improving the patient's outcome.

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